

# Shanghai VLBI Correlator Report

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**Abstract** This report summarizes the activities of the Shanghai VLBI Correlator during 2023 and 2024. Highlights include the deployment of the new correlator platform, participation in the Chinese VGOS Intensives and the VGOS-INT-G series, and fringe testing for the Chiang Mai 13-m radio telescope.

## 1 General Information

The Shanghai VLBI Correlator is hosted and operated by the Shanghai Astronomical Observatory (SHAO), Chinese Academy of Sciences (CAS). It is located at the Sheshan campus, about 40 kilometers from the Xujiahui headquarters of SHAO. The Shanghai correlator has been used in the data processing of the Chinese VLBI Network (CVN), which consists of the Sheshan25, Tianma65, Kunming, Urumqi, and Miyun50 stations. The Shanghai correlator was accepted as an IVS correlator in March 2012. It became operational for IVS data correlation in 2015.

## 2 Component Description

We are operating two types of correlators. The CVN correlator (CVNScorr), a VLBI software correlator developed by SHAO, functions in VLBI data correlation and VLBI signal simulation for deep space navigation.

Shanghai Astronomical Observatory, Chinese Academy of Sciences

Shanghai Correlator

IVS 2023+2024 Biennial Report

The second correlator is the DiFX software correlator, which is dedicated to astronomical and geodetic data correlation.

In 2024, the new platform was installed and tested. As shown in Figure 1, the DiFX software was installed on a high performance hardware platform, with a 864 CPU core cluster system and a total of 2.5 PB storage space. Three Mark 6 units can be used to playback VDIF data. The suite version is Mark6\_1.3c with dplane as 1.22 and cplane as 1.0.26. Features of the DiFX cluster system are listed as follows:

- DiFX 2.6.3 & 2.5.5, HOPS 3.24, nuSolve 0.8.1
- Head nodes: management node, two socket Intel Xeon 4310R CPU (2.1 GHz, 12 cores), 128 GB memory; operations node, two socket Intel Xeon Gold 6334 CPU (3.6 GHz, 16 cores), 128 GB memory
- Computing nodes: 18 computing nodes, two socket Intel Xeon 6342 CPU (2.8 GHz, 24 cores), 256 GB memory, 864 cores in total
- I/O nodes: RAID6, 2.5 PB raw data storage capacity
- Data playback units: three Mark 5B and three Mark 6
- 100 G Infiniband for internal computing network connection
- 1/10 G Ethernet for internal and external network connection.

We did not implement the function of Mark 6 native correlation. A software program similar to VMUX was developed and used to copy the data from modules to our disk array. The average data gathering rate can reach up to 13 Gbps; the de-thread efficiency can reach up to 7.4 Gbps.



**Fig. 1** The hardware platform of the DiFX software correlator.

### 3 Staff

The people involved in the operation, development of the correlator, and the VLBI digital backend are listed below.

#### 3.1 Operations Team

- Fengchun Shu: group head, scheduler, experiment oversight
- Zhong Chen: e-transfer support, cluster administration
- Xuan He: DiFX operation, software maintenance
- Jiangying Gan: data playback, DiFX operation
- Yidan Huang: DiFX operation, post-correlation technique development
- Tianyu Jiang: data playback, DiFX operation
- Wu Jiang: DiFX operation for astronomical data
- Zhanghu Chu: media library
- Shaoguang Guo: Mark 6 maintenance.

Xuan He and Jiangying Gan are the persons to work full-time on geodetic VLBI data correlation.

#### 3.2 Technique Development Team

- Weimin Zheng: group head, software correlator and VLBI terminal development
- Juan Zhang: software correlator development and maintenance
- Lei Liu: software correlator development
- Ping Rui: visualization programming and operation for CVNScorr
- Fengxian Tong: VLBI scheduling and modelling
- Li Tong: VLBI raw data simulation
- Renjie Zhu: CDAS development
- Xiaochuan Qu: CDAS development.

## 4 Current Status and Activities

### 4.1 Data Transfer

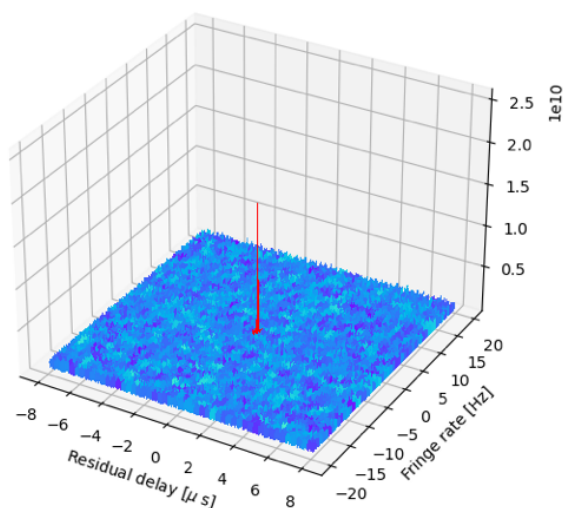
The network link to Seshan25 and Tianma65 is 10 Gbps. The network link to the Urumqi, Kunming, and Beijing stations is 300 Mbps for tracking spacecraft. In deep space tracking sessions, we performed real time data transfer at a 128 Mbps data rate for each station. However, for regular geodetic observations, Urumqi and Kunming stations always ship modules to Shanghai.

In order to process IVS global sessions, we have established a network link to most of the IVS stations and correlators. The regular data rate is 1 Gbps, and the maximum is 4 Gbps when required. KOKEE and three VGOS stations (GGAO12M, KOKEE12M, and MACGO12M), usually ship modules to Shanghai.

### 4.2 Current Status of CVNScorr

In 2024, CVNScorr was applied to the trajectory determination of China's lunar probe Chang'e-7 relay satellite (Queqiao-2) and Chang'e-6. Queqiao-2, operating in the lunar orbit, is equipped with a 4.2-meter diameter parabolic antenna for data relay. The specific pay-

loads, such as the light weight hydrogen maser and the space VLBI terminal, have been mounted onboard. Thus Queqiao-2 can serve as a VLBI station in the lunar orbit. Together with the ground-based Chinese VLBI stations, the first Lunar Orbit VLBI Experiment (LOVEX) system was formed. CVNScorr has been updated to support the data correlations of Lunar-Earth baselines for both deepspace probe and radio source signals. At present, the system has successfully obtained fringes of blazar AO0235+164 and the Chang'e-6 telemetry signal, as illustrated in Figure 2. Further analysis is ongoing.



**Fig. 2** Fringes of AO0235+164 detected on the baseline Lx-T6. Time: 2024-10-18T13:30:00 UTC. Frequency range: 8428–8460 MHz. Accumulation time: 600 seconds. Lx and T6 refer to the onboard antenna and Tianma65, respectively.

### 4.3 IVS Correlation

In 2023 and 2024, we have correlated 42 IVS sessions in total, including six VGOS sessions. Most of the sessions are focused on VLBI absolute astrometry and there is no stringent requirement for data latency. We aimed to deliver the correlation products in three months. More details can be found in Table 1.

So far we have correlated 223 IVS sessions since 2015. The total cumulative data volume is approximately 10.1 PB. It is worth noting that the cumulative data volume from 2023 to 2024 is about 2.4 PB, col-

**Table 1** Statistics of IVS sessions correlated.

Session Name	2023	2024
AOV	4	2
APSG	2	2
IVS-CRF	6	6
IVS-R&D	7	7
VGOS-OPS	2	4
Total	21	21

lected from more than 243 station days. The top five stations with the most observing days are HARTRAO, KOKEE, ONSALA60, MATERA, and WETTZELL. More details are shown in Figure 3.

All APSG sessions and some AOV sessions were scheduled by SHAO. The APSG observing sessions are dedicated to measure positions and velocities of stations in the Pacific Rim. The AOV sessions organized by SHAO were focused on astrometry of weak sources in the ecliptic plane and the Southern Hemisphere. Most recently, the AOV sessions are more focused on mixed-mode observations.

The correlation reports and vgosDb files were uploaded to OPAR<sup>1</sup>. All SWIN files were stored on the local platform. In some cases, we produced FITS-IDI files which can be downloaded at the request of users.

### 4.4 UT1 Intensives

In March 2023, the Chinese domestic UT1 Intensive campaign commenced regular sessions occurring three times per week. The Seshan13–Urumqi13 baseline was utilized with occasional inclusion of Tianma13. A total of 89 database files were generated in 2023 and 76 in 2024. The 5G RF interference was present in Seshan13, and the PCAL was unstable in Urumqi13. Following the analysis of UT1 over the past two years, the results show that the RMS of the UT1 differences compared to IERS C04 is 54.8  $\mu$ s, and the median formal error of the UT1 estimates is 10.7  $\mu$ s.

The VGOS-INT-G sessions have been carried out from early 2024. The participating stations include Ishioka, Seshan13, Yebees, and Santa Maria. A total of 11 out of the 23 sessions have been correlated. To improve correlation efficiency, we are developing an automated processing pipeline for UT1 Intensives.

<sup>1</sup> <https://ivsopar.obspm.fr/upload/>

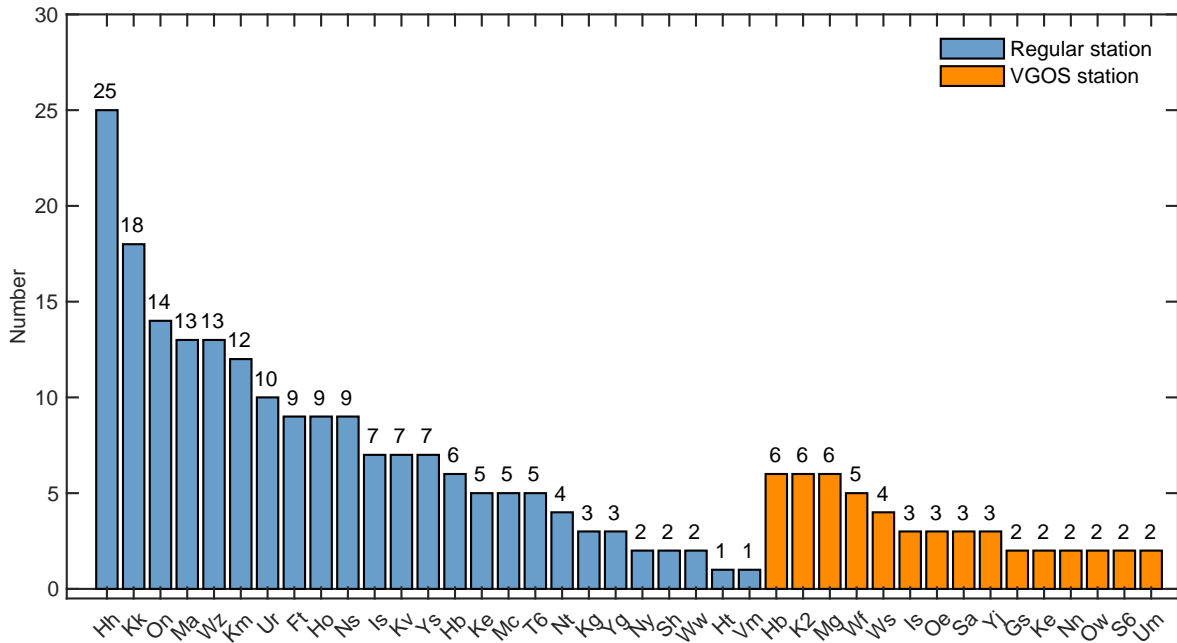


Fig. 3 Statistics of the total number of sessions for each station correlated at Shanghai from 2023 to 2024.

Table 2 The estimated coordinates of the Chiang Mai 13-m radio telescope.

Session Name	X Component /mm	Y Component /mm	Z Component /mm
h24217	-967218798 ± 12	5959981768 ± 60	2049431689 ± 18
h24358	-967218853 ± 6	5959981945 ± 17	2049431775 ± 6
h24360	-967218873 ± 5	5959981994 ± 13	2049431795 ± 7

### 4.5 Fringe Testing for the Chiang Mai 13-m Radio Telescope

For the Chiang Mai, Thailand, 13-m VGOS radio telescope (CHANGM13), we performed fringe tests on August 4, December 23, and December 25, 2024. The first one was observed with CHANGM13, SESHAN13, and URUMQI13. CHANGM13 started late; thus, only 25 scans were successfully recorded in two hours. The second and third tests were performed on the baseline CHANGM13–SESHAN13, with each being one hour long. It is worth noting that CHANGM13 observed and recorded with dual-circular polarizations. All data was processed using VGOS standard processing methods. The estimated coordinates of CHANGM13 derived from the three fringe tests are listed in Table 2.

### 4.6 K-band Geodesy

Within the framework of the East Asian VLBI Network (EAVN), K-band geodetic sessions are performed regularly twice per year. In 2023 and 2024, all of four sessions were correlated at Shanghai, and both FITS and Mk4 files were provided. Those involved in these sessions include: four stations in South Korea, five stations in Japan, three stations in Russia, two stations in China, and one station in Australia.

### 5 Future Plans

We will continue IVS data correlation, with an emphasis on VGOS sessions and AOV mixed-mode sessions. We plan to correlate more international or Chinese domestic UT1 Intensives. Efforts will be made to improve the efficiency of SHAO data transfer and the automa-

tion of Intensive sessions. Finally, in collaboration with NARIT, we will try to make ChiangMai VGOS operational.

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